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(54) Rotor assembly and method of manufacture therefor

(57) A rotor assembly for a stepping motor comprises a rotor magnet 15 having an axial bore 15*a* formed therethrough, and a rotor member 20 formed by moulding a synthetic resin to provide a pinion portion 20*b* and to constitute a unitary structure with the rotor magnet 15. The rotor member 15 includes first and second large diameter portions 20*b*, 20*c* axially spaced from one another between which the rotor magnet 15 is interposed. A method of manufacturing such a rotor assembly for a stepping motor, comprises the steps of placing the rotor magnet 15 between first and second moulding dies 16, 17 having a pinion forming cavity 16*b* and an annular flange forming cavity 17*b*, respectively, and injection molding a synthetic resin to form the rotor member 20 as a unitary structure with the rotor magnet 15. Arrangements in which the magnet has a triangular bore, a double bore, and surface recesses are also disclosed, (Figs. 8, 6 and 11, not shown).

Fig. 3

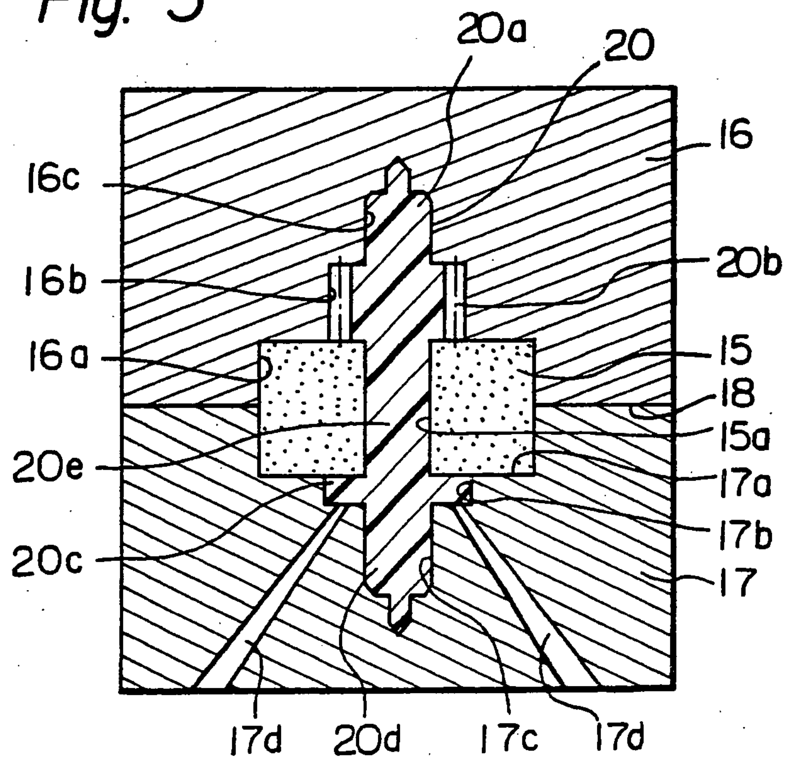

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Fig. 1

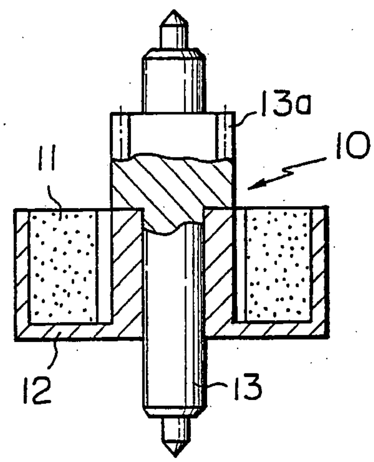


Fig. 2

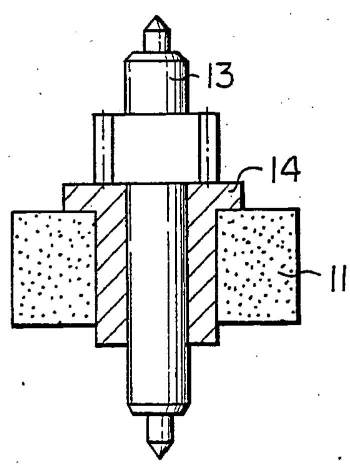


Fig. 3

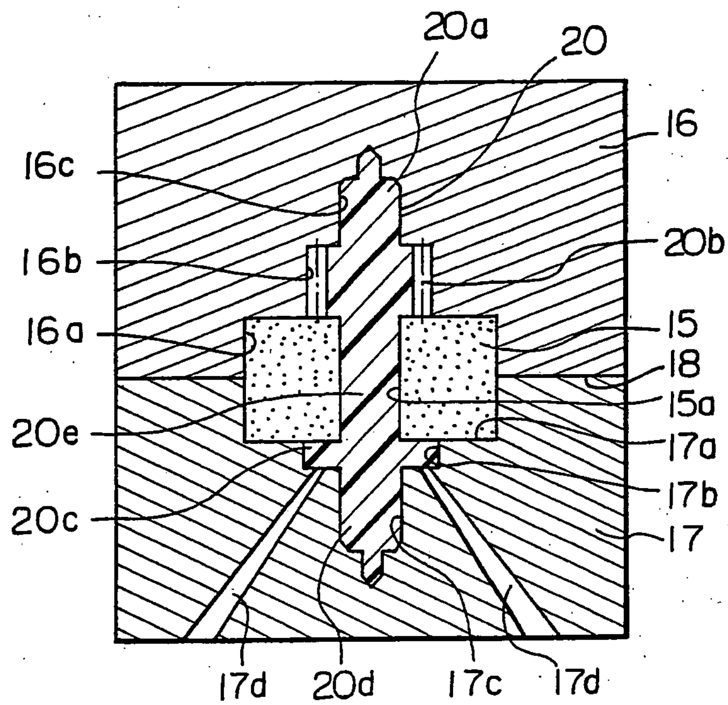

20a
20
16
16c
16b
20b
16a
15
18
15a
20e
17a
17b
20c
17
17d
20d
17c
17d

Fig. 4

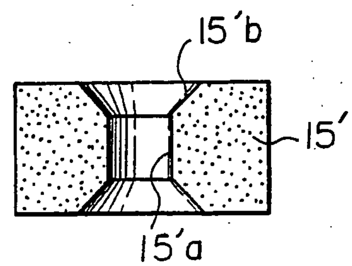

15'b
15'
15'a

Fig. 5

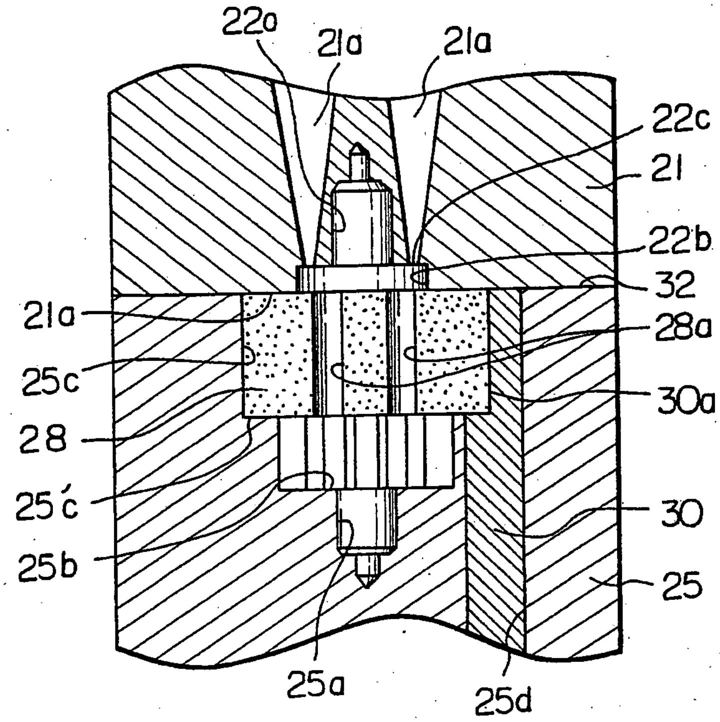

22a
21a
21a
22c
21
22b
32
21a
28a
25c
30a
28
25'c
30
25b
25
25a
25d

Fig. 6

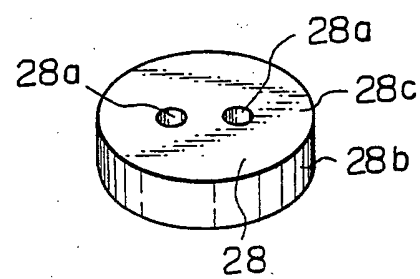

28a
28a
28c
28b
28

Fig. 7

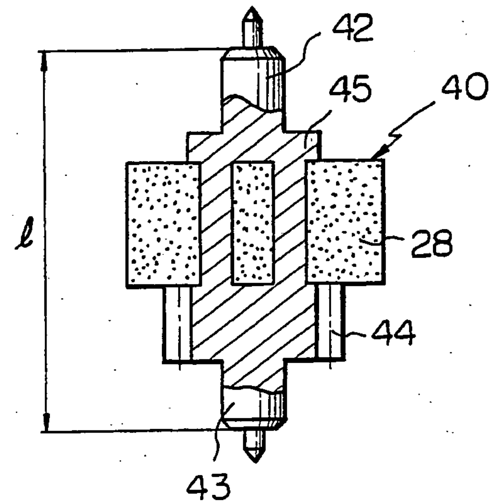


Fig. 8

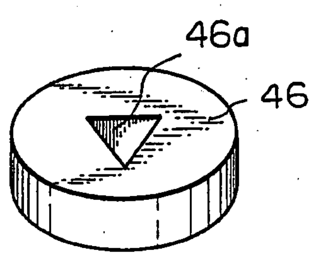


Fig. 9

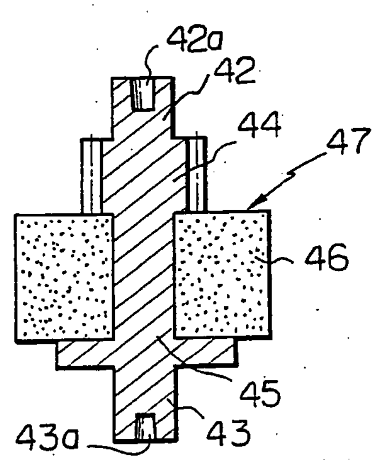


Fig. 10

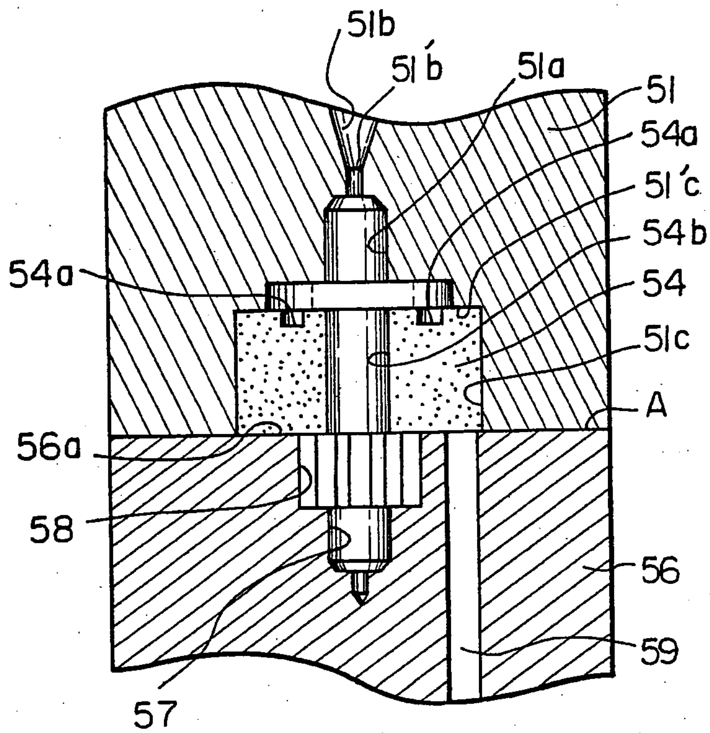

51b
51b'
51a
51
54a
51'c
54b
54a
54
51c
A
56a
58
56
59
57

Fig. 11

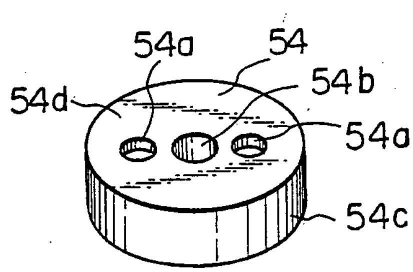

54a
54
54b
54d
54a
54c

Fig. 12

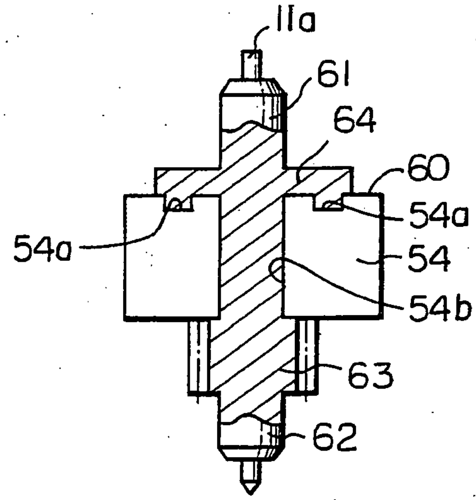


Fig. 13

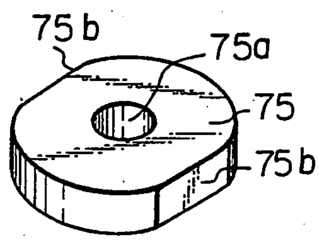
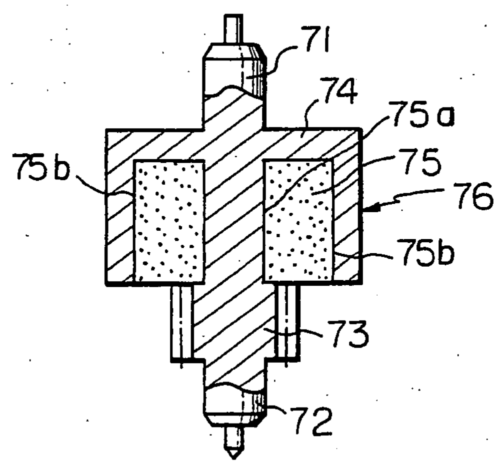


Fig. 14



SPECIFICATION

Rotor assembly and method of manufacture therefor

This invention relates to a rotor assembly for a miniature stepping motor which serves as an electro-mechanical transducer in electronic timepieces.

Electro-mechanical transducers for use in electronic timepieces generally are composed of a drive coil, a stator and a rotor assembly. One way in which the performance of the transducer, which is actually a stepping motor, can be enhanced is to improve the rotor assembly by reducing its inertia and fabricating it from a high-performance magnet. Conventional rotor magnets have made use of PtCo magnets but in recent years magnets made of rare earth materials such as $SmCo_5$ have come into practical use because they have a specific gravity of 8 which is one-half that of the PtCo magnets and a BH_{max} of at least 10 MGOe which represents a higher performance. The performance of these newer, improved rotor assemblies and hence the motors in which they are employed has therefore reached a very high level. However, the rare earth magnets such as $SmCo_5$ are fabricated by sintering intermetallic compounds and are therefore brittle and difficult to machine. This has lengthened machining time and resulted in a poor yield. In addition, when the rotor magnet made of a rare earth material is secured to a rotor pinion, use is made of a metal coupling member which does not satisfy the desire for a rotor of a smaller inertia.

Referring now to Fig. 1 which shows a cross-sectional view of a rotor assembly 10 according to the prior art, the rotor assembly comprises a rotor magnet 11 made of $SmCo_5$, a rotor support member 12 made of metal, and a rotor pinion 13 made of metal and having a pinion 13a. The outer peripheral surface of the magnet 11 is press-fitted into the inner peripheral wall of the rotor support member 12 which is then fixedly mounted on rotor pinion 13.

Fig. 2 is a cross-sectional view of another example of a rotor construction according to the prior art. In this case a rotor retaining member 14 is press-fitted onto the rotor pinion 13 in advance, after which the rotor magnet 11 is secured to the retaining member 14 by means of a bonding agent or the like.

In both of the above examples a separate member is disposed between the magnet 11 and rotor pinion 13, the separate member serving to join the magnet and rotor pinion together. This construction has been required because a rare earth magnet made of an intermetallic compound such as $SmCo_5$ is extremely brittle and tends to crack easily if a force is applied in the direction of thrust. In other words, the prior art has required the interposition of the separate member such as the rotor support member 12 or rotor retaining member 14 in order to prevent the magnet from being subjected to a force applied in the direction of thrust.

These conventional rotor assemblies are disadvantageous in that the rotor support member 12 or retaining member 14 requires that the diameter of the bore located in the center of the magnet 11, thereby resulting in a magnet of a large size. This greatly increases the moment of inertia of the rotor assembly and hence results in a marked reduction in the convention efficiency of the stepping motor. It is also obvious that the support member 12 or retaining member 14 complicates the manufacture of the rotor assembly and raised the cost of manufacture.

According to one aspect of the present invention, there is provided a rotor assembly for a stepping motor, comprising: a rotor magnet having axial bore means formed therethrough; and a rotor pinion including a mold of a synthetic resin formed into a unitary structure with said rotor magnet; said rotor pinion including first and second large diameter portions axially spaced from one another between which said rotor magnet is interposed.

According to another aspect of the present invention, there is provided a method of manufacturing a rotor assembly for a stepping motor, comprising: placing a rotor magnet between first and second molding dies having a pinion forming cavity and an annular flange forming cavity, respectively, said rotor magnet having axial bore means; and injection molding a synthetic resin into said pinion forming cavity, said annular flange forming cavity and said axial bore means to form a rotor pinion into a unitary structure with said rotor magnet.

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a cross sectional view of one example of a prior art rotor assembly for a stepping motor;

Figure 2 is a cross sectional view of another example of a prior art rotor assembly for a stepping motor;

Figure 3 is a cross sectional view of one example of a molding apparatus for carrying out a manufacturing method of a preferred embodiment of a rotor assembly according to the present invention;

Figure 4 is a cross sectional view of a modification of a rotor magnet to be used for the apparatus shown in Fig. 3;

Figure 5 is a cross sectional view of another example of a molding apparatus for carrying out the manufacturing method of another preferred embodiment of a rotor assembly according to the present invention;

Figure 6 is a cross sectional view of a rotor magnet to be used for the apparatus shown in Fig. 5;

Figure 7 is a cross sectional view of another preferred embodiment of a rotor assembly manufactured by the molding apparatus shown in Fig. 5;

Figure 8 is a perspective view of a modification of a rotor magnet shown in Fig. 7;

Figure 9 is a cross sectional view of another preferred embodiment of a rotor assembly according to the present invention employing the rotor magnet shown in Fig. 8;

Figure 10 is a cross sectional view of another example of a molding apparatus for carrying out a manufacturing method of a modification of the rotor assembly according to the present invention;

Figure 11 is a perspective view of a rotor assembly to be used for the molding apparatus shown in Fig. 10;

Figure 12 is a cross sectional view of the rotor assembly manufactured by the molding apparatus shown in Fig. 10;

Figure 13 is a perspective view of another modification of a rotor magnet;

Figure 14 is a cross sectional view of another modification of the rotor assembly according to the present invention employing the rotor magnet shown in Fig. 13.

Referring now to Fig. 3, there is shown a cross-sectional view illustrating a method of manufacturing a rotor assembly according to the present invention. The apparatus comprises an upper mold die 16 and a lower mold die 17 which are shown embracing a rotor magnet 15. The upper mold die 16 has a rotor retaining cavity 16a, a pinion forming cavity 16b concentric with and contiguous with the rotor retaining cavity 16a, and a shaft's end forming cavity 16c concentric with and contiguous with the pinion forming cavity 16b. Likewise, the lower mold die 17 has a rotor retaining cavity 17a concentric with the rotor retaining cavity 16a of the upper mold 16, an annular flange or large diameter portion forming cavity 17b concentric with and contiguous with the rotor retaining cavity 17a, a shaft's end forming cavity 17c contiguous with and concentric with the annular flange forming cavity 17b, and a plurality of injection gates 17d. Designated at 18 is a parting line located between the upper and lower molds 16 and 17. In the molding operation the rotor magnet 15 through which a central bore 15a has previously been formed is inserted into the molding apparatus comprising the upper die 16 and lower die 17. A rotor pinion 20 having an upper shaft portion 20a, a pinion 20b, an annular flange or large diameter portion 20c, a lower shaft portion 20d, and an intermediate shaft portion 20e is then molded by injecting a molding resin from the gates 17d. As a result, the magnet 15 is formed into a unitary construction with the rotor pinion 20 with the magnet 15 being embraced from above and below by the pinion 20b and large diameter portion 20c of the molded rotor pinion 20. In accordance with this construction the magnet 15 and rotor pinion 20 are directly combined into a unitary structure so that the diameter of the bore passing through the center of magnet 15 can be reduced, the moment of inertia of the rotor assembly decreased, and the electromechanical conversion efficiency of the stepping motor greatly improved. In addition, a contraction force resulting from the difference in the coefficient of thermal expansion between the magnet 15 and the synthetic molding resin that forms the rotor pinion 20 gives rise to a force that fixes the pinion 20 and magnet 15 together so that both members can be reliably joined to each other without damaging the magnet 15. It should also be obvious that the magnet 15 and rotor pinion 20 have excellent positional accuracy with respect to each other because the pinion 20 is molded with the outer peripheral surface of the magnet 15 serving as a standard.

The feature of the present invention as described above resides in the fact that the magnet and rotor pinion are directly joined to each other as a unitary construction through a manufacturing method comprising inserting into a molding apparatus the rotor magnet having a previously formed central bore, and subsequently injecting a synthetic molding resin into the molding apparatus to thereby mold the rotor pinion. The present invention therefore makes it possible to provide a high-performance rotor assembly through an extremely simple process and at low cost. It should also be noted that, in accordance with the arrangement of Fig. 3, the gates 17d lead to a bottom surface of the large diameter portion 20c that supports the magnet 15 from the bottom side thereof. The rotor can therefore be extracted from the molding apparatus without harming the shape of the rotor. Moreover, an even more reliable connection between the magnet 15 and rotor pinion 20 can be obtained if the magnet 15' is provided with a central bore 15'a having a tapered portion 15'b as shown in Fig. 4.

Fig. 5 shows another example of a molding apparatus to carry out the manufacturing method of a rotor assembly according to the present invention. The molding apparatus comprises an upper mold die 21 and a lower mold die 25. The upper mold die 21 includes gates 21a, a cavity 22a for forming an extended shaft portion of a rotor pinion, and a cavity 22b for forming a large diameter portion or annular flange of the rotor pinion, the cavity 22b including openings 22c communicating with the gates 21a. The lower mold die 25 includes a cavity 25a for forming an extended shaft portion of the rotor pinion, a cavity 25b for forming the pinion of the rotor,

a cavity 25c for accommodating a rotor magnet 28 which will be described in more detail later, and a knock-out pin 30 movable in a bore 25d of lower mold die 25 and having a stepped portion 30a for supporting a portion of the rotor magnet 28.

The rotor magnet 28, which is shown in more detail in Fig. 6, is made of a rare earth magnet compound such as $SmCo_5$ and is annular in shape. A pair of small through holes 28a extend through the rotor magnet 28 in the thickness direction thereof. The annular body of rotor magnet 28 is positioned and supported diametrically and in the thickness direction thereof by the inner peripheral surface of cavity 25c of the lower die 25 and the stepped portion 30a of knock-out pin 30, which position and support the annular body 28 along its outer peripheral surface 28b, and by the lower face 21a of upper die 21 and the bottom surface 25'c of cavity 25c of the lower die 25. The parting surface 32 where the upper mold die 21 meets the lower mold die 25 agrees with the upper end face of rotor magnet 28, that is, the end face away from the side that includes the cavity 25b for molding the pinion of the rotor.

The method of manufacturing the rotor assembly proceeds as follows. After the rotor magnet 28 has been set in the lower die 25 as shown in Fig. 5, a softened, high molecular substance, namely a synthetic molding resin, is injected from the gates 21a to mold a rotor assembly 40 shown in Fig. 7, the rotor assembly 40 comprising extended shaft portions 42 and 43, a pinion 44 and a large diameter portion 45 molded into a unitary construction. During the molding process the annular body of the rotor magnet 28 is embraced and firmly secured by the pinion 44 and large diameter portion 45. Next, the resin in the gates 21a is pulled upward and the gates is cut off from the large diameter portion 45. The upper die 21 is then raised, the knock-out pin 30 extracted and the molded rotor assembly 40 removed from the lower die 25.

With the above arrangement the rotor magnet 28 can be joined directly to the large diameter portion 45 so that the diameter of the through-holes 28a in the rotor magnet 28 can be greatly reduced with the result that the outside diameter of the rotor magnet 28 can be made quite small. In addition, a contraction force resulting from the difference in the coefficient of thermal expansion between the rotor magnet 28 and the high molecular substance that forms the large diameter portion 45 of the rotor assembly gives rise to a force that fixes the large diameter portion and the magnet rotor together so that both members can be reliably joined without damaging the rotor magnet 28. The rotor magnet 28 has excellent positional accuracy with respect to the extended shaft portions 42, 43 because the shaft portions 42, 43 are molded with the outer peripheral surface of the annular body 28 serving as a standard. Moreover, unlike the conventional rotor magnet which has a bore defining a concentric circle with respect to the outside diameter of the rotor magnet, the rotor magnet 28 of the present invention includes the pair of through-holes 28a into which the molding resin flows and hardens. The rotor magnet 28 will therefore not run idly when the rotor 40 starts to rotate, even if there are dimensional variations caused by environmental changes or aging of the resin. The reliability of the rotor assembly 40 is thus greatly improved. Since the rotor magnet 28 is set in the lower die 25 with the parting surface 32 between the upper and lower dies 21 and 25 being in agreement with the end face 28c of the rotor magnet 28 on the side away from the pinion 44, the molded rotor assembly 40 will remain in the lower die 25 when the molding die is opened. As a result, the rotor assembly 40 can be molded without deviations in length. Furthermore, since the pinion 44 tends to fasten itself to the molding die owing to its complex configuration, disposing the rotor magnet 28 in the same die as the pinion 44 allows them to be knocked out of the die together. Providing the die that forms the large diameter portion 45 at the end of the gates 21a facilitates the flow of the resin during molding and therefore makes it easier to attain dimensional accuracy. In addition, the knock-out pin 30 having the stepped portion 30a at its end in order to support the rotor magnet 28 can be designed to have a large diameter. This facilitates the machining of the knock-out pin 30 and in turn allows the molding die to be machined in a very simple manner.

Figs. 8 and 9 show another embodiment of the rotor assembly wherein a bore 46a passing through the center of a rotor magnet 46 is triangular in shape rather than circular. Accordingly, a molding resin which flows into and hardens in the triangular bore 46a prevents the rotor magnet 46 for idling should the molded rotor 47, shown in Fig. 9, undergo any dimensional variation owing to environmental changes or the like. The effect is therefore the same as that obtained in the embodiment of Fig. 7. The rotor assembly illustrated in Fig. 9 differs from that depicted in Fig. 7 in that the extended shaft portions 42, 43 are provided with respective recesses 42a, 43a. The rotor assembly 47 is axially supported at its recesses 42a, 43a by means of a bearing (not shown) such as a pin located in a timepiece base plate or wheel train bridge, etc., neither of which are shown. In this case the rotor assembly does not include the slender shaft portions extending from each end of the pinion shaft as shown in Fig. 7. The rotor assembly therefore will not warp or bend easily and exhibits a higher impact resis-

tance despite the fact that it consists of a high molecular substance.

In accordance with the invention as described with reference to Figs. 5 to 9, the bore passing through the rotor magnet need not exhibit the high degree of precision seen in the prior art. The machining of the rotor magnet during its fabrication is therefore simplified, costs lowered and yield improved. Since the rotor assembly, with the exception of the rotor magnet, has a unitary construction consisting of a high molecular substance, the cost of manufacturing the overall rotor assembly is reduced and the yield raised. It is thus possible to realize an easily manufactured rotor assembly which has a high degree of dimensional accuracy. In addition, the fact that the outside diameter of the rotor magnet can be reduced, while a high molecular substance is used to mold the rotor assembly exclusive of the rotor magnet, permits the inertia of the rotor to be greatly increased. This makes possible a higher electro-mechanical conversion efficiency as well as thinner and more compact timepieces in which battery lifetime can be prolonged.

Referring now to Fig. 10, there is shown another example of a molding apparatus including an upper mold die 51 and a lower mold die 56. The upper mold die 51 includes a cavity 51a for forming an extended shaft portion of a rotor pinion, the cavity 51a communicating with the opening 51'b of a gate 51b, and a cavity 51c for accommodating a rotor magnet 54 which will be described in more detail later. A lower mold die 56 includes a cavity 57 for forming an extended shaft portion of the rotor pinion, a cavity 58 for forming the pinion of the rotor, and a knock-out pin 59.

The rotor magnet 54, which is shown in Fig. 11, is made of a rare earth magnet compound such as $SmCo_5$ and is annular in shape, the annular body of the rotor magnet having a bore 54b passing through its center and two rotation-preventing portions 54a in the shape of circular recesses formed in one end face 54d of the magnet 54 and extending in the thickness direction thereof. The annular body of rotor magnet 54 is positioned and supported diametrically and in the thickness direction by the inner peripheral surface of cavity 51c of the upper die 51, which positions and supports the annular body 54 along its outer peripheral surface 54c, and by the bottom surface 51'c of cavity 51c formed in the upper die 51 and the upper surface 56a of lower die 56, which support and position the annular body 54 along the outer peripheral portions of both its end faces 54d. The parting surface A where the upper die 51 meets the lower die 56 agrees with the end face of rotor magnet 54 of the side of the cavity 58 for forming the pinion of the rotor.

The method of manufacturing the rotor assembly proceeds as follows. After the rotor magnet 54 has been set in the upper die 51 as shown in Fig. 10, a softened, high molecular substance, namely a synthetic molding resin, is injected from the gate 51b to mold the rotor assembly 60 shown in Fig. 12, the motor assembly 60 comprising extended shaft portions 61, 62, a pinion 63 and a large diameter portion 64 molded into a unitary construction. During the molding process the annular body of the rotor agent 54 is embraced and firmly secured by the pinion 63 and large diameter portion 64. In addition, the injected high molecular substance flows into and hardens in the rotation preventing portions 54a of the annular body 54 so that it is structurally impossible for the rotor magnet to idle with respect to the pinion shaft. Next, the resin in the gate 51b is pulled upward and the gate is cut off from the opening 51'b of the extendes shaft portion 61. When the upper die 51 is raised, the molded rotor assembly 60 will tend to remain fixed in the lower die 56 owing to the complex configuration of the pinion 58. Accordingly, after the upper cavity is raised the knock-out pin is extracted and the molded rotor assembly 60 removed from the lower die 56.

With the above arrangement the rotor magnet 54 can be joined directly to the large diameter portion 64 so that the diameter of the bore 54b passing through the rotor magnet can be greatly reduced with the result that the outside diameter of the rotor magnet 54 can be made quite small. In addition, a contraction force resulting from the difference in the coefficient of thermal expansion between the rotor magnet 54 and the high molecular substance that forms the large diameter portion 64 of the rotor gives rise to a force that fixes the large diameter portion and the magnet rotor together so that both members can be reliably joined without damaging the rotor magnet 54. The rotor magnet 54 has excellent positional accuracy with respect to the extended shaft portions 61, 62 because the shaft portions 61, 62 are molded with the outer peripheral surface of the annular body 54 serving as a standard. Moreover, the rotor magnet 54 includes the rotation-preventing portions in the shape of the circular recesses into which the molding resin flows and hardens, with the result that the rotor magnet 54 will not run idly when the rotor assembly 60 starts to rotate, even if there are dimensional variations caused by environmental changes or aging of the resin. The reliability of the rotor assembly 60 is thus greatly improved. Since the parting surface A between the upper and lower dies 51, 56 agrees with the end face of the rotor magnet 54 on the side of the pinion 63, the parting surface A comes to be positioned adjacent the central portion of the rotor assembly 60 and therefore minimizes any divergence in the centering of the

extended shaft portions 61, 62 such as may result from a defect unintentionally built into the timepiece movement. Disposing the gate 51b at the opening 51'b of the extended shaft portion 61 completely eliminates any possibility that a projection, resulting from a residual portion of the gate, will come into contact with the other components at the time the rotor assembly 60 is installed in a timepiece movement. The danger of such contact is present if the gate 51b is disposed at any other location.

Figs. 13 and 14 show another modification of a rotor assembly according to the present invention. In Fig. 13 a rotor magnet 75 has a bore 75a passing through its center and also includes rotation-preventing portions 75b which are flat in shape and formed by cutting off a section of the outer peripheral surface of the rotor magnet on both its sides. Accordingly, a molding resin which flows and hardens against the outside of the flat, rotation preventing portions 75b prevents the rotor magnet 75 from idling should the rotor assembly 76, molded using a molding apparatus of the type depicted in Fig. 10, undergo any dimensional variation owing to environmental changes or the like. The effect is therefore the same as that obtained in the embodiment of Fig. 12.

It will now be appreciated from the foregoing description that in accordance with the present invention a rotor assembly has a rotor pinion formed by injection molding a synthetic resin into a unitary structure with a rotor magnet whereby the rotor assembly can be easily manufactured with a low cost and in a high yield. The rotor pinion of the rotor assembly has an annular flange serving as a first large diameter portion, and a pinion serving as a second large diameter portion spaced from the first large diameter portion, with the rotor magnet interposed between the first and second large diameter portions whereby axial displacement of the rotor magnet can be highly reliably prevented.

While the present invention has been shown and described with reference to particular embodiments, it should be noted that various other changes or modifications may be made without departing from the scope of the present invention.

CLAIMS

1. A rotor assembly for a stepping motor, comprising:

a rotor magnet having axial bore means formed therethrough; and

a rotor pinion including a mold of a synthetic resin formed into a unitary structure with said rotor magnet;

said rotor pinion including first and second large diameter portions axially spaced from one another between which said rotor magnet is interposed.

2. A rotor assembly according to claim 1, in which one of said first and second large diameter portions comprises a pinion.

3. A rotor assembly according to claim 2, in which another one of said first and second large diameter portions comprises an annular flange.

4. A rotor assembly according to claim 1, in which said rotor pinion also includes an intermediate shaft portion fitted to said axial bore means of said rotor magnet.

5. A rotor assembly according to claim 4, in which said rotor magnet also has first and second tapered portions around said axial bore means.

6. A rotor assembly according to claim 1, in which said axial bore means of said rotor magnet comprising first and second axial bores axially extending through said rotor magnet, and in which said rotor pinion has first and second intermediate shaft portions extending through the first and second axial bores of said rotor magnet.

7. A rotor assembly according to claim 1, in which said axial bore means of said rotor magnet comprises a triangular bore and in which said rotor pinion comprises a triangular intermediate shaft portion extending through the triangular bore of said bore magnet.

8. A rotor assembly according to claim 1, in which said rotor pinion has its both ends formed with a central recesses.

9. A rotor assembly according to claim 3, in which said rotor magnet has its one end face formed with at least one rotation preventing recess, and in which said annular flange of said rotor pinion has at least one rotational preventing projection in engagement with said at least one rotational preventing recess of said rotor magnet.

10. A rotor assembly according to claim 3, in which said rotor magnet has at least one flat side surface, and in which said rotor pinion has at least one axial extension integral with said annular flange and covering said at least one flat side surface of said rotor magnet.

11. A method of manufacturing a rotor assembly for a stepping motor, comprising:

placing a rotor magnet between first and second molding dies having a pinion forming cavity and an annular flange forming cavity, respectively, said rotor magnet having axial bore means; and

injection molding a synthetic resin into said pinion forming cavity, said annular flange forming cavity and said axial bore means to form a rotor pinion into a unitary structure with said rotor magnet.

12. A rotor assembly substantially as shown and described with reference to the accompanying drawings.

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